what would be required to balance the parts, and that the blowing engine must be balanced to run at a given speed and thus be liable to definite changes of motion of the fly-wheel each stroke. In all steam engines with single cylinders it must be recognized that during an instant of the stroke, the fly-wheel must, solely and unaided, maintain the speed and give out the whole power of the engine *by retardation,* while in most engines, during a considerable portion of the stroke, the fly-wheel is aiding, or assisting to impel, the shaft of transmission ; of course receiving a corresponding impulse from other portions of the same stroke.

The unbalanced forces which result from changes of speed of rotation of these unsymmetrical wheels, are transformed into pressures at the axes and have to be sustained by the bearings and resisted by the frame works which carry or support the same, in addition to any strain, proceeding from the mechanism employed in giving rotation or in transmission of power. As pressure or load upon the bearings, the increment of heat derived from friction may cause the total heat to surpass the limit of dispersion in cases where the direct weight of the fly-wheel, approach, as they frequently do, the maximum load of practical endurance on the bearing surfaces. The apparently unaccountable heating of some fly-wheel bearings, where the absolute pressures from load or work are not so great as to cause heating, has been noticed by all practical mechanics, and the considerations now presented offer a reasonable hypothesis in explanation.

In Mahan's Moseley's Mechanics will be found some mathematical investigations leading in this direction, see appendix notes D and E, but a study of these forces and an application of the theorem to the special case of a fly-wheel regulating force or power is needed to complete the theory of practical mechanical construction.

Description of the Wilcox Spouting Water-Well.

By Chas. A. Ashburner, M. S., Assistant Geological Survey.

(*Read before the American Philosophical Society September* 21, 1877.)

The Wilcox Spouting Water-Well for the last nine months has attracted considerable attention, from the immense columns of water and gas which are periodically (every seven minutes) thrown up into air to a height of from 85 to 115 feet. The well is located in the valley of West Clarion Creek, just north of the southern boundary of McKean County, Pennsylvania, and five miles north of Wilcox, a station on the Philadelphia and Erie Railroad 104 miles east of the City of Erie.

The history of the well may be briefly stated as follows :

The Wilcox Well No. 1, or the old Adams Well, was drilled in 1864 (?)

to a depth of 1618 feet, and afterwards continued to a depth of 1785 feet,* where the tools which still remain in the hole, were lost.

The elevation of the top of the conductor above the railroad bridge at Wilcox is 120 feet or 1629 feet above the mean level of Atlantic Ocean. †

The well was drilled "wet," that is, no effort was made to keep the water encountered in the upper part of the hole from following the drill. Great difficulty was experienced in drilling on account of a heavy water vein which was struck at 60 feet depth. This was more particularly the case after the gas veins at 1200 and 1600 feet respectively were met. The water would flow into the hole on top of the gas which it would confine until the pressure of the latter became so great that a huge column of the water would be thrown out of the hole to the annoyance of the drillers. This occurred periodically.

After the tools were lost the upper 400 feet of the well was cased with a four inch casing having a water packer or seed bag attached to its lower end, effectually excluding the water and rendering the hole practically dry.‡

The well was then tubed and it is reported that as much as 100 barrels of oil was pumped and shipped to market; but on account of the great expense of procuring the petroleum, the hole was finally abandoned and the gas allowed free escape into the open air. The gas was afterwards fired and the derrick burned. Three or four years ago a wooden plug was inserted into the casing, which only permitted a partial escape of the gas.

About the beginning of the year 1876, when Well No 2 was started 900 feet distant, a pipe connection was made with Well No. 1, and the gas used as fuel in drilling Well No. 2. The surplus gas was conveyed through a U shaped tube and discharged over a water tank, the water being splashed by the gas over the orifice of the pipe. The pressure of the gas being thus suddenly relieved a ring of ice an inch thick was formed, which remained under the warmest sun. The ice in this case was produced naturally on the same principle that governs the operation of the Kirk freezing machine.

From the time the gas was first struck by the drill up to the latter part of 1876, it seemed to have, according to Mr. Schultz, a constant flow, but as no measurement was made of its pressure it is probable that it gradually diminished.

A little oil being found in Well No. 2, an inch pipe was inserted at the depth of 2000 (the well being 2004 feet deep), and it was proposed to utilize the pressure of the gas to force the oil out of the tubing. The resistance

* Authority, Mr. M. M. Schultz, of Wilcox.

† The elevation of Wilcox being 1509 feet according to railroad levels made subsequent to 1862.

‡ For a complete record of the Well see a paper, by Prof. Lesley, in the Proceedings of the American Philosophical Society, Vol. X., page 238; also one in the Petroleum Monthly of a later date.

1. Number of observations.	2. Gas ceases to flow and water commences running in.	3. Interval.	4. Water ceases to run in and gas commences rising.	5. Interval.	6. Column (of water and gas) commences rising.	7. Interval.	8. Column attains maximum height.	9. Interval.	10. Height.	11. Number of pulsations.	12. Column vanishes.	13. Interval.	14. Water ceases to run in and gas commences rising.	15. Interval.	16. Column commences rising.	17. Interval.	18. Column attains maximum height.	19. Interval.	20. Height.	21. Column vanishes.	22. Interval.
1					1.21.30 6.30	.15	1.24.45 7.15	1.	101		1.25.45 7.15	1.35	1.27.20 7.40	.45	1.28.05 7.35	.10	1.28.15 7.35	.30	3	1.28.45 7.30	1.15
Interval.																					
2	1.30.	.55	1.30.55	05	1.31. 7.	1.	1.32 7.	1.	99	4	1.33. 6.50	1.30	1.34.30 7.	1.10	1.35.40 6.35	.10	1.35.50 6.40	.25	2½	1.36.15 6.55	
Interval.																					
3	* 14.05		† 11.05		1.38. 7.15	1.	1.39. 7.	.50	87	3	1.39.50 6.55	1.40	1.41.30 6.45	.45	1.42.15 6.05	.15	1.42.30 6.30	.40	2½	1.43.10 6.20	.55
Interval.																					
4	1.41.05 6.45	55	1.45. 7.	15	1.45.15 6.55	.45	1.46 6.40	.45	87	7	1.46.45 7.	1.30	1.48.15 7.	.05	1.48.20 7.25	.40	1.49. 6.55	.35	5	1.49.30 7.15	1.20
Interval.																					
5	1.50.50 6 55	1.10	1.52. 6.50	10	1.52.10	.30	1.52.40 6.35	1.05	83	6	1.53.45 6.55	1.30	1.55.15 7.	.30	1.55.45 7.20	.10	1.55.55 7.25	.50	8	1.56.45 7.15	1.
Interval.																					
6	1.57.45	1.05	1.58.50		—— 13.35		1.59.15 7.	1.25	99	6	2.00.40 6.40	1.35	2.02.15 6.45	.50	2.03.05 6.35	.15	2.03.20 6.30	.40	2½	2.04. 6.45	
Interval.																					
7	* 13.50		† 13.45		2.05.45 7.	.30	2.06.15 7.	1.05	86	1	2.07.20 6.55	1.40	2.09. 6.45	.40	2.09.40 6.50	.10	2.09.50 6.55	.55	2½	2.10.45 7.	.50
Interval.																					
8	2.11.35 6.45	1.	2.12.35 6.40	10	2.12.45 6.35	.30	2.13.15 6.45	1.	91	5	2.11.15 6.45	1.30	2.15.45 6.45	.45	2.16.30 6.40	.15	2.16.45 6.35	1.	4	2.17.45 6.45	.35
Interval.																					
9	2.18.20 6.45	.55	2.19.15 7.05	05	2.19.20 7.05	.40	2.20. 7.	1.	115	6	2.21. 7.	1.30	2.22.30	.40	2.23.10	.10	2.23.20	1.10	5	2.24.30	.35
Interval.																					
10	2.25.05	1.15	2.26.20	05	2.26.52	.35	2.27.	1.	97	6	2.28.										

* The gas did not cease to flow, but rose continuously between the smaller and larger columns.

† The water did not flow in from the pool surrounding the top of the conductor.

offered to the flow of the gas was so great that after a few hours the gas ceased to flow entirely from both wells, Nos. 1 and 2. After 36 hours of inactivity it commenced flowing again with greater energy. In the early part of January, 1877, the pressure of the gas seemed to increase suddenly; but not finding a free passage from Well No. 1, on account of the wooden plug which had been inserted into the casing and which the gas was unable to blow out, the casing was broken at a depth of 175 feet, and the upper portion lifted bodily out of the well. As soon as this occurred the conditions which had existed during the process of drilling were restored, and a column of water was thrown out of the hole every eight minutes to a height of from 80 to 90 feet, and lasting from three to five minutes (M. M. Schultz). This continued until about the middle of May, when the gas from both wells ceased to flow without any obstruction having been knowingly placed in its way.

On the 14th of July, at 1 A. M., the gas made its appearance again and began to throw the water with great energy to a height ranging from 85 to 115 feet; also with a smaller column from three to eight feet high in the intervals between the larger ones; the phenomenon recurring every seven minutes.

During the time that the water columns are thrown out of the well the gas is thoroughly mixed up with the water and is readily ignited. The sight during the flow of the larger column is grand, particularly at night. The water and fire are so promiscuously blended that the two elements seem to be fighting for the mastery.

On July 19th, I closely watched the well for two hours, from 1.19 to 3.22 P. M., and carefully recorded the time of each change in the condition of the water and gas as they spouted from it, noting the number of pulsations in the larger column, and determining its maximum height by triangulation.

On page 129 is a tabulated scheme of the observations from 24 minutes and 30 seconds past one to 28 minutes past two o'clock.*

By an inspection of the intervals between the recurring phenomena, it will be at once seen that there is a marked regularity in the action of the well; in fact, the slight irregularities observed may in a measure be attributed to the personal equation of the observer. In the time included

*NOTES.—1. The time in the table is recorded in hours, minutes and seconds, and the height of the columns in feet.

2. The intervals in the vertical columns show the time in minutes and seconds or seconds alone, during which each phenomenon lasted. The intervals in the horizontal columns show the time in minutes and seconds between the recurrences of the phenomenon.

3. In columns Nos. 4 and 11, where it is stated "the water ceased to run in," it is meant that no water flowed into the hole from the pool surrounding the top of the conductor. It is probable that the water from the water vein at 60 feet depth flows into the well incessantly.

from 10.39 A. M. to 3.15¾ P. M., there were counted 39 of the larger water columns, making the average time between the commencement of each column 6 minutes and 55 seconds.

The accompanying graphical representation will present the action more vividly to the eye. It will be noticed that prior to the water columns No. 3 and 7 no water flowed into the hole from the pool surrounding the conductor. Directly after the larger columns vanish, the water flows into the hole, indicating that all the water is blown out of the well.

Occupying every consecutive 7 ± minutes we have the following sequence of events (See observation No. 9 of the table):

The water from the "water vein" at the depth of 60 feet, and from the pool surrounding the top of the conductor flows into the well for 55 seconds, during which time no gas is detected issuing from the hole. At the end of this time the water from the pool ceases to run in, and the gas rises bubble by bubble for 5 seconds. A column of water and gas now commences rising, makes 6 pulsations, attains a maximum height of 115 feet in 40 seconds, and vanishes in 1 minute. The water from the pool and water vein immediately flows into the well for the second time, continuing for 1 minute and 30 seconds, during which time no gas flows out. At the end of this time the gas rises bubble by bubble for 40 seconds, when the smaller column of water and gas rises, attaining a maximum height of 5 feet in 10 seconds, and vanishes in 1 minute and 10 seconds. The gas still continues to rise but no water flows into the well from the pool for 35 seconds, when the same series of phenomena repeat themselves. Such are the facts.

The explanation of the action may be readily imagined. The pressure of the gas having relieved itself in throwing out of the well the larger column, the water flows into the hole until the pressure of the gas becomes so great again that instead of rising up in small bubbles through the water it rushes out of the well, throwing the water at the same time to a height of from 3 to 8 feet. After the column has vanished the gas continues to rise in great quantities, keeping the water from flowing in from the pool, until the pressure is exhausted. The water now flows into the well till the pressure of the gas in its reservoir has increased to such an extent that it thrusts out of the hole the larger column of water to a height of from 85 to 115 feet.

The smaller column of water is probably produced by the gas coming from the smaller vein at 1200 feet depth, while the larger column is thrown up by the gas coming from the greater vein at a depth of 1600 feet. But, of course, neither the one nor the other column is produced by either of the gas veins exclusively, for the gas must be flowing from both horizons more or less all the time. It will be noticed that more water flows into the hole directly after the larger column has been thrown up, and that the smaller column throws up less water, and *vice versa*.

It was not possible to obtain the pressure or amount of gas coming from the well. The estimated pressure at the time that 175 feet of casing was blown from the well was about 250 lbs. to the square inch. It is possible that the accumulated pressure at the time that the larger water columns are thrown up may be as high as 250 lbs.; but the constant pressure of the gas if unobstructed by the water would probably not be more than 50 lbs.

The action of the Wilcox well is nothing novel, but the observations are interesting and valuable from the fact that a complete record and history of the well have been preserved, and the accompanying facts add much to what has been recorded of similar wells.

As early as 1833*, Dr. S. P. Hildreth, in a paper on the "Saliferous Rock Formation in the Valley of the Ohio" says: "In many wells, salt water and inflammable gas rise in company with a steady uniform flow. In others, the gas rises at intervals of ten or twelve hours, or perhaps as many days, in vast quantity, and with overwhelming force, throwing the water from the well to the height of fifty to one hundred feet in the air, and again retiring within the bowels of the earth to acquire fresh power for a new effort. This phenomenon is called 'blowing,' and is very troublesome and vexatious to the manufacturer."

A well drilled by Peter Neff, Esq., near Kenyon College, in Knox Co., Ohio, presented similar features to the Wilcox well. At a depth of 600 feet gas was struck which threw out of the well at intervals of one minute, a column of water to a height of 120 feet. "The derrick set over this well has a height of 60 feet. In winter it becomes encased in ice, and forms a huge translucent chimney, through which, at regular intervals of one minute, a mingled current of gas and water rushes to twice its height. By cutting through this chimney at the base and igniting the gas in a paroxysm, it affords a magnificent spectacle—a fountain of water and fire which brilliantly illuminates the ice chimney."

Many of the persons who have visited the Wilcox well during the summer have made a comparison of heights with geysers of the Geyser Basin, and I have been repeatedly referred to for information in regard to the latter.

The following table, compiled from Dr. Hayden's report of the U. S. Geological Survey, 1871, gives some figures of the geysers along the Fire Hole River, in Wyoming Territory.

Name.	Height.	Diameter.	Time.	Observer.
Grand.....	200 feet.	6 feet.	20 minutes.	Dr. Hayden.
Giant.....	140 "	5 "	3 hours.	N. P. Langford.
"	90 to 200 ft.	———	3 hrs. 30 min.	Lieut. Doane (1870)
"	140 feet.	———	1 " 20 "	Dr. Hayden.
Giantess...	250 "	6 to 15 in.	20 minutes.	" "
Beehive ..	219 "	———	18 "	" "

*See American Journal of Science, July, 1833, quoted in Early and Latter History of Petroleum, by J. T. Henry.

Note.—Since writing the above it has been reported to me that the gas in well No. 2 has been partly confined, and the increased pressure in well No. 1 has somewhat altered the action of the water and gas. The large column is thrown to a greater height.

Discussion.

Mr. Briggs remarked that the conditions which produce the phenomena of Spouting Wells and of Geysers are sufficiently simple but perhaps not generally comprehended. One of the essentials for the peculiar eruption and periodic discharge which they exhibit, is the enlargement or funnel shape of the upper portion of the cavity; so that at or near the final effort of each pulsation, the confined gas or steam shall be suddenly relieved of a part of the pressure of column or head, and the gas or vapor beneath the liquid, in so large a bubble as to form a chamber or reservoir of gas or steam, be allowed to expand against a less pressure than that under which it had generated or been supplied when lifting the column from the bottom of the well to the place where the well enlarged.

By tracing the phenomenon of a single pulsation, as it may be assumed from the foregoing description to have occurred, it will be seen that, commencing with that period when the gas has exhausted its pressure by a nearly free discharge, after the complete expulsion of the water and relief from any resistance except that proceeding from the depth of water in the shallow pool formed about the mouth of the well (presumed to be from 1 to 2 feet in depth at most), after the pressure of gas falls below this presumed depth, the steps in operation are as follows: A portion of the water in the pool at the top flows back upon the well, quickly forming a column within it and compressing the gas beneath, which is in much too large volume to rise through the water in small bubbles, although some bubbles may force their way up when the return of water first begins and discharge eruptively as they approach the surface, lifting a spatter of water at such discharge, but finally the water column will have acquired such height as to flow quickly down the well and receive such augmentation of quantity as the water bearing strata may supply, filling the well nearly to the bottom, some considerable portion of solid water passing below the level of the upper gas bearing strata and compressing the lower gas by the momentum of the water to the point where its gas supply may be stopped from flowing. Possibly a bubble of gas from the upper gas bearing strata will be formed in the column and be carried downwards, as there is 400 feet of depth of well between these two strata and we can scarcely conceive of 400 feet of solid water, or even 300, to reach between the two levels; but at all events a column of water of some height exists between the upper and lower gas strata when the ultimate recession of water into the well has occurred. The gradual supply of gas from both sources of supply now overcomes and slowly elevates the mass of water, however broken by gas bubbles, giving a nearly uniform pressure of column during such time as it is elevated in the tube (or well) of uniform section, that is until the column reaches the point where the casing was blown out ; there being a great bubble of confined upper as well as a volume of confined lower gas in the bore of the well. Ultimately, before the column reaches the point of enlargement, the volumes of gas become much more considerable than those of the water. It may be assumed, as it is essential to do for the resulting expulsion, that of the 1400 feet (about) of total depth below the top of the casing not over 300 or 400 feet of water column (if so much) ever exists in the well. The water which up to this stage has ascended slowly, now rises into the enlarged mouth caused by the absence of casing, and relieved from pressure of column, as the height reduces, the expanding gas of the upper bubble, becomes eruptive, and the first discharge of 3 or 4 feet height of water is effected. The relief of pressure attendant upon the removal of a portion of the water above into the pool, lifts the lower column of water to above the upper gas bearing strata; but before it reaches the enlargement at the casing the force of expulsion of the upper bubble will have been expended, and the water thus discharged will have returned wholly or in part to the well again, and will have restored the original column and its pressure upon a larger volume of gas with the supply of both gas bearing strata. The regular supply of gas continuing, the column again reaches the point of enlargement, and now, with a great reservoir of gas to expand, the final effort of a pulsation is consummated, with a discharge of gas and water of 85 to 115 feet in height. Allowing for the mixture of gas and water in reducing the gravity of the column, it is possible that the greatest *pulsation of emergence* at the mouth of the well cannot be more than the equivalent to a height of 60 to 90 feet or 30 to 45 pounds per square inch.

In the case of the Geyser the same necessity of conformation of the pit or hole, so far as regards the funnel-shaped mouth to relieve the pressure of water column at or near the top, exists. The heated water is then the reservoir of energy for producing an eruption ; a large volume of steam being formed at once when relief of pressure occurs. The phenomena of periodic discharge following a course similar to that described as coming from emission of gas from a strata when the cooled return water comes in contact with the volcanic heated rocks at the bottom of the hole, producing a steam pressure more rapidly than the water circulation will permit the heat to be transferred to the surface of the water quietly and thus lifting the column to the point of enlargement where its pressure is reduced.

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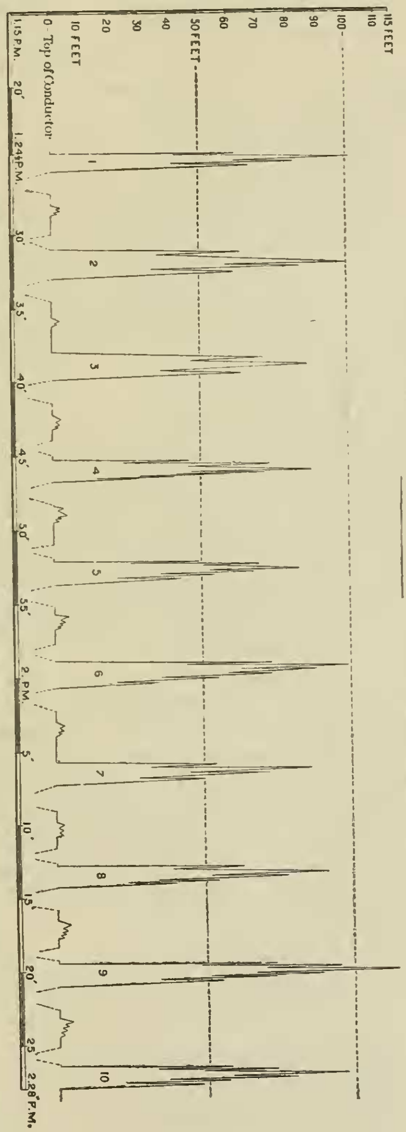
Graphical Representation of the Wilcox Spouting Water-Well, McKean Co. Pa.

The unbroken line on and above the base is the profile of the Water issuing from the Conductor; the Gas rising from the Well at the same time. The broken line below the base indicates the time that no gas is issuing from the Well, and the time that the Water from the Pool around the Conductor is flowing in.

The height of the major pulsation in each column was alone determined.



Observations made July 19th 1877, by Chas. A. Ashburner: M. S. Asst. Second Geological Survey of Pa.

G.B.H.